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The ATAGS (Advanced Technology Anti-G Suit) design process initially relied on comments made by human test subjects to subjectively evaluate the effects of design changes on inflation characteristics. A standardized test method was needed to objectively quantify the effects of the design changes and also to compare the inflation characteristics of other anti-G suits. Therefore, a test was designed to measure the filling characteristics of different anti-G suits fitted to a standard mannikin. Several factors had to be considered in developing a test method that was both operationally significant and provided consistently valid data. The factors considered were: don/doff requirements, the effects of evacuation of the anti-G suits prior to testing, mannikin position and additional life support equipment worn with the anti-G suit. Parameters measured to assess the inflation characteristics were flow rate, fill times, and differential pressures in the suit.

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PROCEDURES AND METRICS FOR ANTI-G SUIT EVALUATIONS

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ABSTRACT *The ATAGS (Advanced Technology Anti-G Suit) design process initially relied on comments made by human test subjects to subjectively evaluate the effects of design changes on inflation characteristics. A standardized test method was needed to objectively quantify the effects of the design changes and also to compare the inflation characteristics of other anti-G suits. Therefore, a test was designed to measure the filling characteristics of different anti-G suits fitted to a standard mannikin. Several factors had to be considered in developing a test method that was both operationally significant and provided consistently valid data. The factors considered were: don/doff requirements, the effects of evacuation of the anti-G suits prior to testing, mannikin position and additional life support equipment worn with the anti-G suit. Parameters measured to assess the inflation characteristics were flow rate, fill times, and differential pressures in the suit.*

INTRODUCTION In the past, the Armstrong Laboratory has relied heavily on comments made by human test subjects taking part in cockpit integration, centrifuge, and flight tests to evaluate the effects of design changes on anti-G suit inflation characteristics. While the opinions of these experienced subjects are extremely valuable, a test method was needed to objectively evaluate the effects of these design changes and to compare the inflation characteristics of different anti-G suits. The design and development of a reliable test method that yielded reproducible results is reported herein.

METHODS Two anti-G suits were used in this study to demonstrate that the test was applicable to a variety of anti-G suits. The anti-G suits were tested on a mannikin; therefore the size that best fit the mannikin was used for each anti-G suit. Three parameters were measured to evaluate the efficacy of the test method: peak flow rate, fill time to 10.5 psi at the right and left calf, and total suit volume. These inflation characteristics were measured using the data acquisition and process control system detailed in Figure 1 (1). This system consists of: an Apple Macintosh® II microcomputer with LabView® software, and a test stand with a flow meter and two pressure transducers.

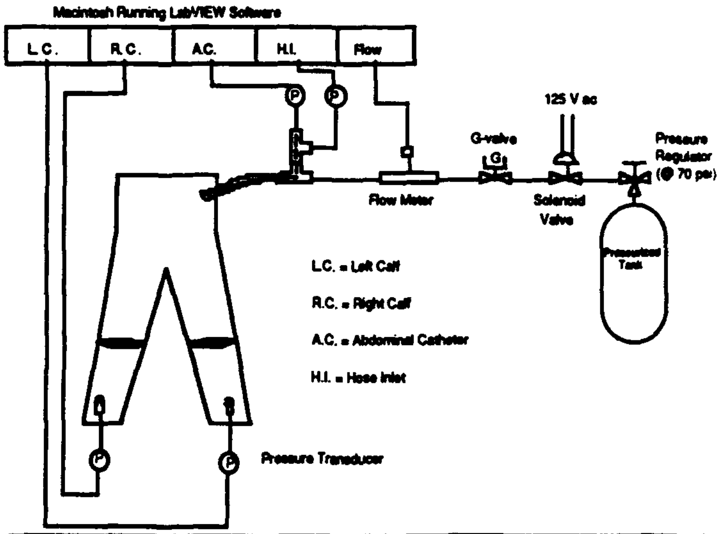

Figure 1. Data acquisition and process control system.

The pressures in the right and left calves were obtained by connecting the transducers to ports in the lower legs of the anti-G suits.

RESULTS The primary requirement of the test method was that it provide reproducible, accurate data. It was also important that the test be operationally relevant. If an anti-G suit is tested under unrealistic conditions, the results might not be valid for the flying community.

The first step was to determine the configuration in which the anti-G suit would be tested. It was decided that the mannikin would wear a parachute harness over the anti-G suit, and that it would be seated in an Aces II seat. These two factors ensured that the test was operationally representative, as well as providing the most demanding conditions for the flow of air. To further mimic the operational setting, we decided to include an ALAR Hi-Flow G-valve in the process control system, to serve as a regulator. A load was placed on the valve to simulate 9 +Gz. This provides the maximum operational airflow into the anti-G suit, so that the anti-G suit, not the test system, was the limiting factor in the fill time and flow rate.

While trying to develop a reliable, yet operationally relevant method to test anti-G suits, several factors had to be considered. The first was whether donning & doffing the anti-G suit would influence the results. We also postulated that if each anti-G suit was evacuated with a mild vacuum before each pressure test, it would be tested under the same conditions and therefore ensure reproducibility of the results. We conducted a series of experiments: to determine if the inflation characteristics change significantly each time an anti-G suit is fit on a mannikin; and to determine if evacuation of an anti-G suit provides a common baseline and provides reproducible data.

To test the effects of donning and doffing on the inflation characteristics, we conducted an experiment in which the anti-G suits were pressurized to 10.5 psi for 25 trials. The 25 trials were divided into 5 sets of 5 inflation tests. In between each set of trials, the anti-G suits were removed from the mannikin and subsequently refit.

Peak flow, fill time to 10.5 psi, and volume data were acquired for each trial. We used an analysis of variance (ANOVA) to determine whether the variation between fittings was greater than the variation within a fitting. Table 1 shows a significant difference for the variation between and within fittings for the peak flow and volume parameters.

Table I. Don/doff analysis results for anti-G suit A.

	MEAN SQUARE ERROR BETWEEN FITTINGS	WITHIN FITTINGS	F	P
PEAK FLOW (scfm)	1.091	0.173	6.323	0.002 *
FILL TIME (seconds) TO 10.5 PSI	0.081	0.054	1.488	0.244
VOLUME (liters)	0.628	0.219	2.864	0.050 *

The same results can be seen in Table II, which also demonstrates a significant difference for the variation between and within fittings for the peak flow and volume parameters.

Table II. Don/doff analysis results for anti-G suit B.

	MEAN SQUARE ERROR BETWEEN FITTINGS	WITHIN FITTINGS	F	P
PEAK FLOW (scfm)	3.757	.086	43.388	< 0.001 *
FILL TIME (seconds) TO 10.5 PSI	.403	.185	2.182	0.108
VOLUME (liters)	3.399	.112	30.354	< 0.001 *

These results demonstrate that donning & doffing the anti-G suit does affect the data and should be incorporated into any test method. Thus a biased estimate of the average response is avoided and the range of response is better defined.

Our second research objective was to determine if the evacuation of the anti-G suit with a vacuum would ensure more reproducibility of the results. A study similar to the don/doff analysis was conducted. The anti-G suits were pressurized to 10.5 psi for 25 trials. The 25 trials were divided into 5 sets of 5 trials, and the anti-G suits were refit on the mannikin in between each set of trials. To provide a common baseline, the anti-G suits were evacuated with a mild vacuum (150 Torr) before each trial.

Once again, peak flow rate, fill time to 10.5 psi, and volume data were acquired for each trial. We used an ANOVA to compare the variation between the two conditions: Vacuum and No Vacuum. When the anti-G suit in Table 3 was evacuated, the variation in the Vacuum condition was not significantly different from the variation in the No Vacuum condition.

Table III. Evacuation analysis results for anti-G suit A.

		MEAN SQUARE ERROR			
		NO VACUUM	WITH VACUUM	F	P
WITHIN FITTINGS	PEAK FLOW(scfm)	0.173	0.138	1.251	0.622
	FILL TIME (sec) TO 10.5 PSI	0.054	0.117	2.169	0.091
	VOLUME (liters)	0.219	0.398	1.815	0.191
BETWEEN FITTINGS	PEAK FLOW(scfm)	1.091	1.262	1.157	0.891
	FILL TIME (sec) TO 10.5 PSI	0.081	0.046	1.733	0.607
	VOLUME (liters)	0.628	3.574	5.692	0.121

The same was true for the second anti-G suit shown in Table 4, with two exceptions: the peak flow and volume parameters in the Within Fittings analysis. The Mean Square Error for these parameters were significantly different, but in both cases the variation of the data was larger under the Vacuum condition than the variation under the No Vacuum condition.

Table IV. Evacuation analysis results for anti-G suit B.

		MEAN SQUARE ERROR			
		NO VACUUM	WITH VACUUM	F	P
WITHIN FITTINGS	PEAK FLOW (scfm)	0.086	6.365	73.504	< 0.001 *
	FILL TIME (sec) TO 10.5 PSI	0.185	0.176	1.048	0.918
	VOLUME (liters)	0.112	1.695	15.141	< 0.001 *
BETWEEN FITTINGS	PEAK FLOW(scfm)	3.757	29.208	7.774	0.072
	FILL TIME (sec) TO 10.5 PSI	0.403	2.302	5.710	0.120
	VOLUME (liters)	3.399	1.153	2.947	0.320

These results suggest that evacuating the anti-G suit does not improve the variability, and in some cases may increase the variability more than not evacuating the anti-G suit. Therefore evacuation should not be included in any test method, because it does not improve the reliability and it is not operationally relevant, since pilots seldom, if ever, evacuate their anti-G suits.

CONCLUSION An effective test method was designed and developed to provide reproducible, accurate data for a variety of anti-G suits. Repeatability incorporated into the test provides for an increased sample size and allows for better comparisons of different anti-G suits because the anti-G suits do not have to be tested at the same time. The test method is also operationally relevant, thus the data is applicable to the flying community. An optimal anti-G suit engineering evaluation, that met the above criteria included: the use of a parachute harness, a realistic seating system, a current G valve as a regulator, and repeated donning and doffing of the anti-G suit. Development of the test method demonstrated that the anti-G suit should be vented to atmosphere and not evacuated.

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BIOGRAPHIES

Grady L. Ripley is a research engineer for KRUG Life Sciences, San Antonio Division. Prior to joining the San Antonio Division, she was with KRUG Life Sciences, Houston Division at NASA, Johnson Space Center, where she was instrumental in planning and monitoring certification/acceptance tests for all hardware in the International Microgravity Laboratory (IML-1) spacelab experiment, MVI (Microgravity Vestibular Investigations), on STS 42. Her current responsibilities include supervising the Armstrong Laboratory's Life Support Equipment Development Laboratory (LSEDL) and designing, developing, and testing various personal protective garments, including the ATAGS. Ms. Ripley received a bachelor's degree in Biomedical Engineering from Texas A&M University, College Station, Texas.

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Daniel H. Bauer has been employed as a mathematical statistician at Armstrong Laboratory, Brooks AFB, Texas for the past 4 years. During his tenure, he has provided statistical consultation and analysis to scientists working in the areas of acceleration research, decompression sickness research, chemical defense, and human factors as related to flying safety. Mr. Bauer has a Bachelor of Science degree in mathematics from the University of Chicago.